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Ion Escape from Non-Magnetized Planets toward the Planetary Wake

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A new MHD code is developed to study the escape of ions from non-magnetized planets towards the nightside wake and to study its effect on the nishtside plasma structure taking into account the different escape velocities along the magnetic field line for different ion species. Electrons are treated as a massless fluid whose pressure gradient affects dynamics of all ion species. Chemical reactions and related source terms for mass, momentum, and energy equations are incorporated in the code. The results are discussed in detail for the Mars case.

We found that two competing processes contribute to the maintenance of the nightside ionosphere. One is the downward plasma supply from the magnetotail. The ionospheric plasma (mainly O+ and O2+ ions plus small amount of CO2+) outflowing from the dayside ionosphere are accelerated tailward by magnetic tension and then pushed toward the tail center by the JxB force. The increase of plasma pressure at the tail center produces a downward plasma flow to supply plasma to the nightside ionosphere. This process is the most important to produce and maintain the ionosphere on the nightside above 200 km height. On the other hand, the night side ionosphere below 200 km can be maintained by weak ionization rate assumed and by horizontal ionospheric convection from dayside.

The plasma flow pattern and ion density distribution in the induced magnetotail of Mars strongly depends on the IMF magnitude. When IMF is weak, the structure is axially symmetric and a large ring-shaped plasma vortex is produced behind the planet. On the other hand, when IMF is large, a strongly asymmetry exists between the distribution in two orthogonal plains, that is, between the x-y plane and x-z plane. (The coordinate system is taken such that the x-axis is directed toward the sun and the x-y plane contains IMF.) In the x-y plane, a three-ray structure is observed: Two boundary rays are produced by ions escaping parallel to the field lines that are severely draped around the planet. On the other hand, the central ray is produced by the ions that have been accelerated tailward by magnetic tension and pushed toward the tail axis by the JxB force. The density structure in the x-z plane (the plane corresponding to the Earth's plasma sheet) has only a central ray that is produced by converging flows towards the tail axis.

We also estimate the total amount of escaping ions for each ion species and its dependence on solar wind parameters.